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Geothermal Energy: A Primer on State Policies and Technology

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Legislators are becoming increasingly interested in how renewable energy technologies such as geothermal, wind, biomass and solar power can enhance the nation's energy security, stimulate economic development, improve air quality, and protect customers from volatile energy prices. Many states that have relied on fossil fuels or hydroelectric power are expanding their use of renewable energy in order to diversify their energy portfolio. This diversification can protect customers from high electricity prices that stem from constraints in fuel supplies or water shortages that result from drought. Policymakers also are interested using these technologies to reduce air emissions.

Renewable energy power plants also create construction, operation and maintenance jobs. Another economic development opportunity associated with renewable energy is available for individuals who own land with abundant renewable resources; they often can lease their land to project developers in exchange for royalty payments that are based on the output of the project. These royalties are playing a major role in the expansion of the domestic wind power industry. Because many of the best renewable resources are located in remote, rural areas, states are especially interested in the potential that exists for renewable energy to help spark ailing rural economies.

Resource

Another renewable resource that may produce revenue for states and localities is geothermal energy. Geothermal energy is most easily defined as heat that originates deep within the earth and is manifest in the form of steam or hot water. Humans have used geothermal energy for thousands of years; since the beginning of the 20th century it has been used to generate electricity. Geothermal power plants produce clean power and occupy very little land compared to other power generating technologies. Typically, they emit no nitrogen oxides, very low amounts of sulfur dioxide, and about one-sixth the carbon dioxide that a natural gas plant emits.

Benefits and Challenges of Geothermal Energy

Benefits

- Geothermal power plants provide steady and predictable baseload power.
- Electricity can be generated at an affordable rate of \$0.05 per kWh to \$0.08 per kWh, compared to \$0.03 per kWh to \$0.05 per kWh for natural gas and wind and \$0.15 per kWh to \$0.30 per kWh for photovoltaics.
- Plants can generate tax revenue for localities and royalties for landowners and can create construction and maintenance jobs for residents.
- Responsibly maintained resources can provide power for many years.
- Geothermal power plants operate about 95 percent of the time.
- Power plants are small, require no fuel purchase and are compatible with agricultural land uses.
- Geothermal plants produce a small amount of pollutant emissions compared to traditional fossil fuel power plants.

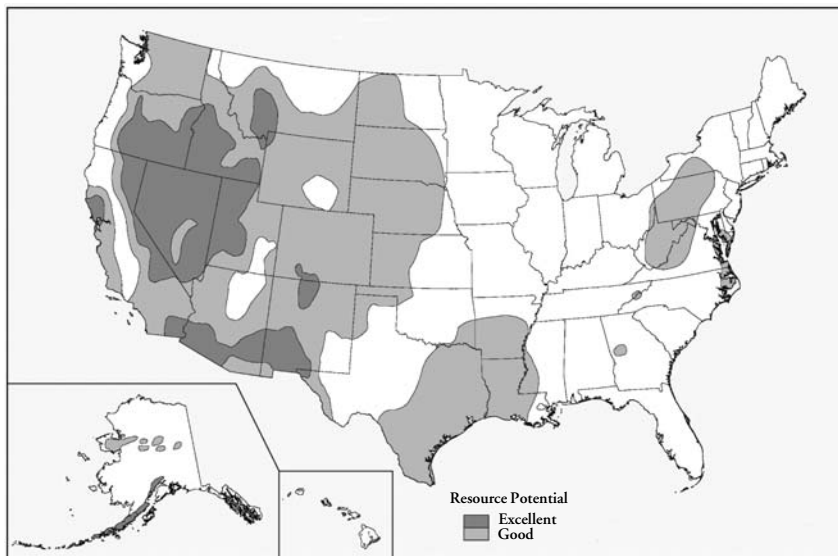
Challenges

- The leasing process can be very cumbersome, especially on federal lands.
- Although costs have decreased in recent years, exploration and drilling for power production remain expensive.
- Using the best geothermal resources for electricity production will require an expansion of the transmission system.
- The success rate for discovering geothermal resources in new, untapped areas is approximately 20 percent. In areas where wells already are producing, the chance of locating more wells nearby is about 80 percent.
- Geothermal power plants are often in scenic areas, but they take up little land and can easily be designed to blend into their surroundings.
- The temperature and pressure of geothermal resources diminishes over time.

The hottest domestic resources are located in the rapidly growing western United States, but useful low and moderate temperature resources are spread throughout the country (figure 1). More than twenty geothermal installations generate power in California, Hawaii, Nevada and Utah. Collectively, these plants generate about 2,200 megawatts (MW) of electricity each year, enough to power roughly 2 million average American homes. California and Nevada rely on geothermal power for between 6 percent and 10 percent of their total electricity supply. The U.S. Geological Survey predicts that currently identified resources in the United States could provide more than 20,000 MW of power and that undiscovered resources may equal five times that amount.

The greatest benefit of geothermal resources—compared to other renewables—is that geothermal power plants provide constant, baseload power (i.e., power that plant operators can dispatch to meet demand). Solar and wind resources produce power intermittently. One drawback of geothermal power is that the heat content of wells slowly declines over time as the resource is tapped. If properly maintained, however, fields of hot geothermal resources can generate electricity for 50 years or more and, in fact, power plant equipment usually deteriorates before the resource is depleted. However, using geothermal power to generate electricity over extended periods will likely require tapping new wells within geothermal fields as old ones cool.

Figure 1. U.S. Geothermal Resource



Note: This resource map represents approximate areas where more intensive geothermal uses will most likely be found. The darkest areas, labeled as “Excellent,” indicate regions where electricity applications are potentially possible. Areas labeled as “Good” are more likely to represent direct use applications (e.g., direct heating of buildings, aquaculture, greenhouses and industrial processes).

Source: National Renewable Energy Laboratory, 2000.

Technology

This report focuses on the use of geothermal resources to generate electricity, but other common uses warrant mention. Using geothermal heat pumps and certain “direct use” applications can save considerable energy. These technologies use lower temperature resources to heat and cool buildings, to heat greenhouses and in industry to pasteurizing milk or dry concrete, for example. The three types of geothermal energy production are direct-use, heat pumps and electricity generation.

Geothermal Direct Use

Direct use applications tap hot underground water and distribute the heat through pipes to heat buildings. These systems can replace traditional heating sources such as natural gas-fired boilers, furnaces or hot water heaters. Some cities and towns have installed large direct use heating systems—called district heating—that heat many buildings from a common source. Geothermal direct use also has agricultural applications. The agricultural sector uses geothermal resources for fish farms, to heat greenhouses and to dehydrate veg-

etables. Direct use applications use geothermal resources at temperatures of between 70°F to 302°F—lower than those required for electricity generation. Approximately 1,300 of these systems operate in the across the United States.

Geothermal Heat Pumps

Geothermal heat pumps can be used nearly anywhere because they simply transfer heat between a building and the ground.

Geothermal heat pumps (GHPs) can be used nearly anywhere because they simply transfer heat between a building and the ground. These pumps use the relatively stable temperature of the ground to heat buildings in the winter and cool them in the summer. In the summer months, GHPs capture heat from a building and pipe it into the ground. In winter, this process is reversed; the system extracts heat from the ground and releases it into a building. Because GHPs actually transfer heat between buildings and the earth, they operate cleanly and efficiently, burning no fuels. In fact, these systems are about three times more efficient than even the most energy-efficient furnaces on the market today. Currently, more than 500,000 geothermal heat pumps are in use in the United States, and approximately 50,000 are installed annually.

Geothermal Electricity Production

Geothermal power plants use underground steam or hot water from wells sometimes drilled as deep as a mile or more into the earth. The steam (or water that is made into steam) is piped up from the well to drive a conventional steam turbine, which powers an electric generator. Typically, the resource is returned to the ground to recharge the reservoir. Three types of geothermal power plants are dry steam, flash steam and binary cycle. Dry steam plants draw from reservoirs of steam, while both flash steam and binary cycle plants draw from reservoirs of hot water. Hot water plants currently are the major source of geothermal power, both domestically and internationally. In the United States, hot water plants operate in California, Hawaii, Nevada and Utah.

Dry Steam. Dry steam reservoirs are the easiest to use, but are rare; only five such fields have been discovered to date. The only commercially developed steam field in the United States is the Geysers, located in northern California, which began producing electricity in 1960. This was the first source of geothermal power in the country, and now is the largest single source of geothermal power in the world.

Flash Steam. Hot water reservoirs are much more common. They provide the majority of geothermal electric generation worldwide. These power plants flash—or separate—hot

water (typically at temperatures greater than 300°F to 350°F) into steam and liquid phases; the steam spins a turbine just as in dry steam plants. Although multiple flash systems are technically possible, double flash systems have proven to be the most economically viable. These types of power plants are located in California, Nevada and Utah.

Binary Cycle. A third and rapidly growing technology for generating electricity is binary generation. Rather than flashing the resource to produce steam, binary systems transfer the heat of the geothermal resource to a secondary working fluid that vaporizes to drive the turbines. Binary systems can convert low-temperature resources (as low as 100°C or 212°F) to electricity more efficiently than flash systems. Another advantage of using a secondary fluid is that corrosive elements naturally found in the geothermal water or steam do not come in contact with the turbine. Binary systems also are more environmentally attractive because the geothermal resource is contained and is not exposed to the air, water or land surface. The use of binary applications grew rapidly from the mid 1980s to the present; more than 350 MW of binary generation currently exist in California, Hawaii, Nevada, New Mexico and Utah.

Cost

Renewable energy power plants have more upfront costs than fossil fuel plants; however, renewable power plants do not require continuous fuel purchases to generate power. Most of the costs associated with geothermal power plants involve upfront expenditures for exploration and for drilling and constructing power plants. In the United States, initial costs for developing geothermal resources and constructing large geothermal power plants (with capacity of greater than 1 MW) are around \$2,000 per installed kilowatt (kW) depending on the temperature and chemistry of the resource. Geothermal field development alone may equal up to half of the cost associated with a geothermal power plant. The capital cost for gas plants is approximately \$750 per kW, for coal-fired plants between \$900 per kW and \$1,200 per kW and for wind generating facilities approximately \$1,000 per kW.

Renewable power plants do not require continuous fuel purchases to generate power.

Renewable power plants generate electricity at a steady rate over the life of the power plant because the renewable resource is free. Fossil fuels, especially natural gas, are susceptible to market forces that can cause price spikes like those witnessed in early 2001. The price of electricity produced using a typical geothermal power plant currently ranges from \$0.05 to

\$0.08 per kilowatt-hour (kWh). By comparison, modern natural gas-fired power plants and wind turbines in areas with strong winds are producing power for approximately \$0.03 per kWh. (Without the federal production tax credit of \$0.015, the cost of wind-generated electricity is commonly closer to \$0.05 per kWh.) Solar electric—or photovoltaic—technology generates power for between \$0.15 per kWh and \$0.30 per kWh.

Economic Development

Beyond generating revenue by selling electricity, geothermal plants also produce revenue from extracting minerals and direct use. The economics of geothermal power improve if developers can remove minerals that exist in solution with the geothermal fluid. Zinc, silica and manganese which commonly are found in geothermal resources, have numerous industrial uses. Silica, for example, can be used as a rubber additive and in computer chips. Current market prices for silica range from approximately \$0.70 to several dollars per pound, depending on the quality of the mineral.

The lease fees, taxes and production royalties that geothermal developers pay can generate significant revenue for states, localities and landowners.

The lease fees, taxes and production royalties that geothermal developers pay can generate significant revenue for states, localities and landowners. Geothermal developers pay federal and state income taxes on the profits from their operations. Royalties that they pay for the right to produce on federal or state lands are similar to severance taxes. In most states, however, no severance tax derives from producing on private lands. In addition, many states assess a property tax on the value of the resource, and localities impose a property tax on the value of the power plants. Geothermal power plants also create jobs in exploration and drilling, power plant construction, operation and maintenance, and equipment supplies.

Geothermal development can generate revenue for states such as **Idaho** and **Nevada**, where the federal government owns most of the land, and in **California**, where the state owns the resource. For example, in 1999 in **Nevada**, where half the total federal fees and royalties are returned to the state, almost \$2 million went to the state. (Nevada has approximately 235 MW of installed geothermal electric generating capacity that provides 5.5 percent of the state's power.)

Direct use applications like heating greenhouses, drying crops and raising fish also can create economic development opportunities for states. In **New Mexico**, for example, four large greenhouses use geothermal power directly to grow a variety of plants. These facilities

cover more than 50 acres, employ nearly 500 people and generate nearly \$23 million in revenue annually. In **Nevada**, two large onion and garlic dehydration facilities use geothermal energy to yield nearly 2,000 pounds of product every hour. In **Idaho**, fish farms yield more than 2 million pounds of fish each year, and greenhouses there raise plants, flowers and vegetables on 15 covered acres. Low temperature geothermal resources also are used for fish farming in some southeastern states from **Georgia** to **Louisiana**.

Market Size and Growth

The U.S geothermal industry is a \$1.5 billion per year enterprise. Worldwide, there currently are approximately 8,000 MW of installed capacity in 21 countries. The United States is the largest provider, with about 2,200 MW of installed capacity that produce more than 18 million megawatt-hours of electricity. The domestic geothermal industry grew substantially in the 1980s, when approximately 900 MW of electric generation capacity were installed in the United States, mostly in Nevada and California. In the 1990s, however, geothermal development slowed as the industry lost government market incentives and because it could not compete with the then-cheap natural gas prices.

The U.S geothermal industry is a \$1.5 billion per year enterprise.

This industry is expected to grow over the next five years. Approximately 600 MW of new generation is planned, mostly in California and Nevada, with some small plants (smaller than 10 MW) expected in Idaho, New Mexico and Utah. Geothermal industry stakeholders anticipate annual growth rates of 5 percent to 10 percent for electric generation, 10 percent to 15 percent for heat pump applications (mainly in the eastern United States and Midwest) and 5 percent to 10 percent in direct use, mainly for industrial and agricultural applications. International markets also have great potential. The U.S. Department of Energy predicts that during the next 20 years, foreign countries are expected to spend between \$25 billion and \$40 billion to build geothermal power plants. This could create significant opportunities for U.S. suppliers of geothermal goods and services.

Challenges

Technical and regulatory barriers exist that prevent the more widespread use of geothermal power. Leasing and siting can be tedious because many state and federal laws vary greatly both in how they define “geothermal resources” and how they determine who owns the rights to them. In addition, exploration and drilling and power transmission are costly and

present their own set of unique technical challenges. Drilling for geothermal resources also is risky because new, untapped resources are discovered in only about 20 percent of the wells.

Technical Barriers

Although the cost of generating power from geothermal resources has decreased by 25 percent during the last two decades, exploration and drilling remain expensive. Drilling costs alone can account for as much as one-third to one-half of the total cost of a geothermal project. Technical barriers also are associated with building transmission lines to deliver geothermal-generated electricity to market. Geothermal resources often are located in remote areas beyond the reach of the power grid, and constructing power lines is an expensive and contentious endeavor. Locating the best resources can be difficult, and many dry wells are found before valuable ones are discovered. Geothermal fields may contain dozens of wells, each of which may cost up to \$4 million to explore. Also, because rocks in geothermal wells are extremely hot and hard, drilling equipment must be replaced frequently.

The cost of generating power from geothermal resources has decreased by 25 percent during the last two decades, but exploration and drilling remain expensive.

Another technical issue that is impeding the development of both renewable energy and fossil fuels in the United States is the fact the nation's power transmission system is in dire need of an upgrade. This system, which delivers electricity over great distances, frequently is congested and is quickly becoming obsolete. Not only are new power lines expensive to construct, but they also may be difficult to site because they often face opposition from people who live close to proposed routes.

Regulatory Barriers

Most geothermal resources are located on federal or state-owned lands; rarely do developers own the land. Developers often encounter hurdles before drilling can begin because the states and the federal government have different ways of defining the resource, determining ownership, issuing permits and negotiating leases. In fact, most court cases dealing with geothermal resources involve accessing resources on private lands where the federal or state government retains the mineral rights.

Defining the Resource. In defining geothermal resources, legislative bodies face the task of distinguishing geothermal resources from other natural resources in order to determine ownership. In many states, geothermal water and steam are not clearly defined as separate from other resources such as minerals or water. This confusion has led to disagreement

about who actually owns the rights to a geothermal resource because, depending on how the state defines “geothermal,” the owner of the water or mineral rights also may own the rights to geothermal resources.

Each state defines the resource differently, but most state definitions are similar to the federal definition. The federal Geothermal Steam Act of 1970 defines geothermal resources as follows:

“Geothermal steam and associated resources means (i) all products of geothermal processes, embracing indigenous steam, hot water and hot brines; (ii) steam and other gases, hot water and hot brines resulting from water, gas or other fluids artificially introduced into geothermal formations; (iii) heat or other associated energy found in geothermal formations; and (iv) any by-products derived from them.”

Under the Geothermal Steam Act, the federal courts ruled that on federally owned lands the government owns the mineral rights and that geothermal resources are part of the mineral estate.

In **Washington**, a “geothermal resource” means only the heat energy that it is practical to use for commercially producing electricity. Such resources are characterized as neither mineral nor water, but a resource unto itself. **Alaska**, in a similar move, tried to separate the regulation of hot water for electricity generation (above 120°C) from low temperature resources that could be used directly. **Utah** and **Wyoming** characterize “geothermal” as water, while **Hawaii** characterizes it as mineral.

Determining Ownership. Once a developer identifies a good geothermal resource prospect, the next task is to determine who owns both the resource and the land above it. Many times, the landowner owns the rights to both; however, sometimes the geothermal rights are severed from the surface ownership. In this case, the developer must negotiate with both owners before occupying the surface and drilling the underlying resource.

The federal government owns more than half the land in the western United States and it claims ownership of geothermal resources wherever it holds the mineral estate. The states have taken different approaches to determining ownership, depending on how the geother-

Under the Geothermal Steam Act, the federal courts ruled that on federally owned lands the government owns the mineral rights and that geothermal resources are part of the mineral estate.

mal resource is characterized. In **Washington**, geothermal rights belong to the surface owner, and in **Wyoming**, where geothermal is characterized as water, geothermal resources are considered a public resource and available through appropriation. **Alaska** claims ownership of all its geothermal resources, but the property owner has first priority to lease them from the state.

Leases. Leases are either competitive (awarded to the highest bidder), or noncompetitive (obtained for a simple filing fee), depending on where the resource is located. On federal lands, geothermal resources are available for lease for a specified period of time. Land within areas where proven resources exist is leased competitively; all other lands are available for noncompetitive lease. Most state leases provide for a noncompetitive primary term that varies from five years to 10 years and can be extended as long as the developer is actively engaged in production. All state leases have provisions for an extension once commercial production begins. The states have primary responsibility for decisions related to developing geothermal resources on state-owned lands. In cases where states have not enacted their own environmental protection laws, all the provisions of federal law apply. On private land, the state is responsible for ensuring compliance with all federal and state environmental statutes. Each state has developed a notice of intent mechanism that provides access to land for casual exploration.

Most states have adopted an access system that is similar to the federal government's.

Most states have adopted an access system similar to the federal government's. **Alaska**, **California** and **Oregon** have provisions for issuing exploration or prospecting permits in addition to allowing both competitive and noncompetitive leases. **Washington** negotiates each lease separately, while in **Colorado**, state lands are available for development through negotiation or by competitive bid.

Policy Options

The following list includes some common approaches that states are using to develop or expand various renewable energy resources. Simply because a state is included on this list does not mean that the policy in that state applies only to geothermal energy; it may apply to other renewable energy sources.

Renewables Portfolio Standard (RPS)

This policy requires electricity retailers to ensure that a certain percentage—commonly between 5 percent and 7 percent—of the power they sell be produced from renewable sources. Some states that have enacted this legislation include Arizona, Connecticut, Massachusetts, Minnesota, Nevada, New Mexico, Pennsylvania, Texas and Wisconsin.

State Renewables Purchase

These programs require a state to purchase a certain amount of its energy from renewable sources for use in state-owned facilities. Since state agencies are large energy users, this commitment can help to support the renewables market in the state. Arizona, Colorado, Hawaii, Oregon and Texas have adopted this measure.

State Production Tax Credit

This option provides a tax credit (usually around 1 cent per kWh) for electricity generated from renewable resources. These production-based payments reward the actual generation of electricity rather than just the installation of equipment. Maryland, Minnesota, New Mexico and Oklahoma offer production tax credits.

State renewable energy purchases can support the renewable energy market in a state.

Property Tax Incentives

Property taxes usually are in the form of exemptions, exclusions and credits. The majority of these tax exemptions are structured so that any additional value that a device adds to the property is not included in the value of the property for taxation purposes. For example, if a renewable heating system costs \$2,000 compared to \$1,000 for a traditional system, the renewable system will be assessed at \$1,000. Because property tax is collected locally, some states give local authorities the option of providing a property tax incentive for renewable energy devices. Twenty-four states—including California, Connecticut, Illinois, Iowa, Kansas, Maryland, Montana, Nevada, New Hampshire, Oregon, Vermont, and Virginia—provide property tax incentives for renewables.

Sales Tax Incentives

Sales tax incentives usually exempt renewable energy equipment from the state sales tax. These incentives are available in Alaska, Arizona, Connecticut, Florida, Hawaii, Iowa, Maryland, Massachusetts, Minnesota, Nevada, New Jersey, North Dakota, Ohio, Rhode Island, Vermont and Washington.

Green Market Portfolio

This policy requires power providers to offer a menu of different renewable—or “green”—products to customers. An example of a green product would be a program that allows customers to support renewable energy by purchasing 100 kWh blocks of electricity generated from renewable resources for \$2 to \$3 per month. The utility itself can administer and market these programs to customers, or it could contract for the work with another company that specializes in providing these services. Programs like this currently are available in New York and Oregon.

Disclosure and Certification Programs

These programs require electricity retailers to display on a customer’s bill the mix of fuel sources that are used to generate electricity. The reasoning behind this policy is to provide a sort of “truth in advertising” for electricity retailers. Polls have shown that consumers want more of their power to come from renewable sources, and many are willing to pay a premium for this. Demands for green power may increase as a result, as people see the actual amount of energy that is generated from nonrenewable sources. This effort is under way in 25 states, including California, Colorado, Delaware, Florida, Illinois, Michigan, Montana, New Jersey, New York, Ohio, Texas and West Virginia. Some of these states have restructured their electricity markets, while others have not.

The nation’s hottest resources are located in the West, but useful low temperature resources are found in nearly every state.

Conclusion

Renewable energy technologies such as geothermal power can protect customers from volatile energy prices, enhance national energy independence, and stimulate economic development. Geothermal power plants generate steady and reliable baseload power, occupy very little land, and emit no nitrogen oxides and very low amounts of sulfur dioxide and carbon dioxide. The nation’s hottest resources are located in the West, but useful low temperature resources are found in nearly every state. Although the costs have decreased during the last few decades, exploration and drilling remain expensive and gaining access to resources can be cumbersome, especially on federal lands. Many states, with both restructured and regulated utility markets, have enacted a variety of policy options to create incentives to develop or expand their renewable energy resources.

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